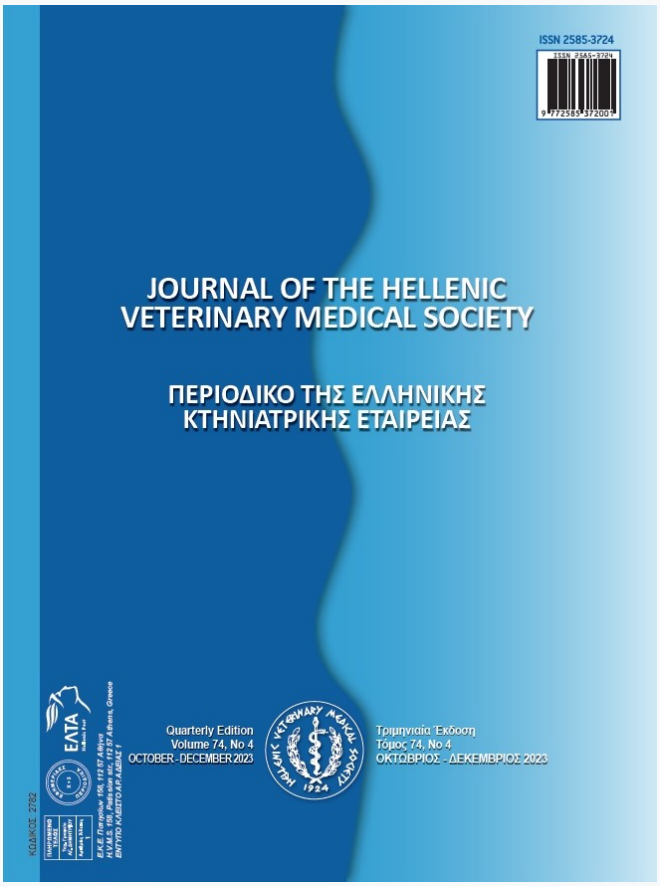
Journal of the Hellenic Veterinary Medical Society

Vol 74, No 4 (2023)



Abnormal twinning in goat: a review

A Pourlis, G Papakonstantinou, V Papatsiros

doi: 10.12681/jhvms.35100

To cite this article:

Pourlis, A., Papakonstantinou, G., & Papatsiros, V. (2024). Abnormal twinning in goat: a review. *Journal of the Hellenic Veterinary Medical Society*, *74*(4), 6317–6328. https://doi.org/10.12681/jhvms.35100

J HELLENIC VET MED SOC 2023, 74 (4): 6317-6328
ΠΕΚΕ 2023, 74 (4): 6317-6328

Review article
Ανασκόπηση

Abnormal twinning in goat: a review

A. Pourlis[1], G.I. Papakonstantinou[2], V.G. Papatsiros[2]

[1]*Laboratory of Anatomy Histology and Embryology, Faculty of Veterinary Sciences, University of Thessaly, Greece*

[2]*Clinic of Pathology, Faculty of Veterinary Sciences, University of Thessaly, Greece*

ABSTRACT: A survey of congenital malformations relating to abnormal caprine twins was carried out. According to the degree, sites, and angle of fusion, they have various external variations and are classified as free asymmetric, conjoined symmetric or asymmetric twins (heteropagus or parasitic twins). The aim was to describe and summarize these defects. Among the recorded abnormal twining in goats, several common defects relate to thoraco-omphalopagus. A series of dicephali and diprosopus monsters have also been registered. At last, cases of free asymmetrical twins have been reviewed. There is also a report of a case of unequal conjoined-parasitic twins. The pathogenetic mechanisms of this condition, frequently reported in veterinary practice, are discussed. However, the etiopathogenesis of imperfect twins remains puzzling. The importance of embryonic duplications is commonly associated with dystocia.

Keywords: conjoined twins; teratology; double monsters; caprine; congenital malformations.

Corresponding Author:
Aris Pourlis, Laboratory of Anatomy Histology and Embryology, Faculty of Veterinary Sciences, University of Thessaly, Trikalon 224, 43100, Karditsa, Greece
E-mail address: apourlis@vet.uth.gr

Date of initial submission:
Date of acceptance:

INTRODUCTION

The congenital malformations are conditions which occur during the prenatal development of animal organisms. These conditions are observed in various cases of veterinary practice. The domestic goat is an animal model to evaluate potential cause-effect relationships between the environment and congenital malformations. In addition, goat husbandry is widely propagated in various areas all over the world both in terms of extensive and intensive animal production. Greece has a dynamic caprine population which contributes to the national economy. The record of congenital defects is essential in veterinary medicine. In farm animals especially in goat, embryonic malformations represent one of the largest groups of congenital anomalies and is a common cause of dystocia and delivery of stillborn embryos. Congenital duplications of the entire fetuses (conjoined twins, double monsters, or defective twining) are unique and interesting among congenital defects (Hiraga and Dennis, 1993). These duplications form a spectrum of structures which vary from slight duplication to near separation of two individuals. According to the degree, sites, and angle of fusion, they have wide external variation (Arthur, 1959) and are classified as free asymmetric, conjoined symmetric or asymmetric twins and unequal conjoined twins (heteropagus or parasitic twins). However, in the Nomina Embryologica Veterinaria (2017), a simpler classification of twinning has been suggested. According to the latter, there are the Gemini acardiaci and the Gemini conjucti. The Gemini conjuncti are further subdivided in Gemini conjuncti symmetrici and assymetrici (Table 1).

In order to facilitate the quotation of various malformations a concise terminology must be mentioned. The term pagus means fixed or fused or united and always follows an anatomical term such as omphalo- (umbilicus), thoraco- (thorax), cephalo- (head), ischio- (hip), cranio- (skull), rachi- (spine), pygo- (rump), para- (side).

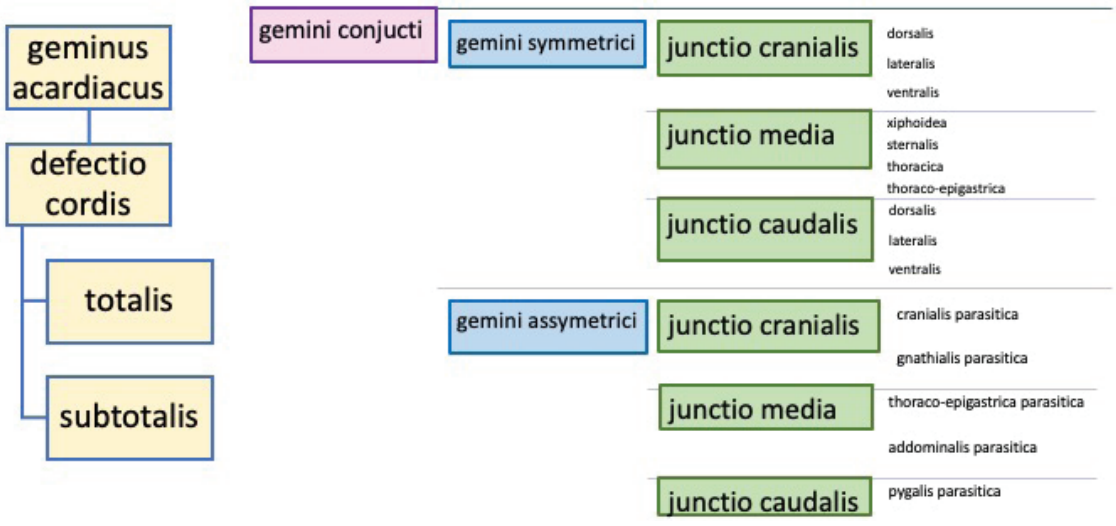
The only other terms usually needed are the numeric prefixes di-, tri-, and tetra- (two, three, and four) and terms for anatomical structures that may be united, e.g., -prosopus (face), -cephalus (head), -brachius (fore limb), and -pus (hind limb), as well as an occasional compound term used to describe twins intermediate between the standard types (e.g., prosopothoracopagus).

Autosite and parasite monsters consist of two components of very unequal development, the one (autosite) being normal or nearly so, and the other (parasite) quite incomplete and attached to the first as a dependent growth, usually adhering to some point upon the ventral side.

CONJOINED TWINS

The International Committee on Veterinary Embryological Nomenclature (2017) provided a clear and relatively precise classification of conjoined twins in Nomina Embryologica Veterinaria (NEV). According to the N.E.V., the malformed conjoined twins are subdivided into two main categories namely symmetric and asymmetric. Following, both the symmetric and asymmetric twins are classified into three general conjunction groups: cranial, medial, and caudal conjunction. Classically, the conjoined twins can

Table 1: The classification of abnormal twins according to Nomina Embryologica Veterinaria



be divided into dorsal, lateral, and ventral conjunction types. The rostral ventral conjunction comprises the cephalopagus, thoracopagus and omphalopagus. The caudal ventral conjunction comprises the ileoischiopagus, whereas the lateral conjunction is the parapagus diprosopus and parapagus dicephalus. When the twins are joined dorsally, they are the craniopagus, rachipagus and pygopagus.

Cranio-facial duplications

Cephalic parapagia, a rare congenital anomaly caused by the fusion of two monozygotic embryos, is characterized by a single body and a spectrum of duplication of craniofacial structures. In Table 2 the caprine cases of cranio-facial duplication are quoted. The duplications are mainly subdivided into dicephalus and diprosopus phenotype (Figure 1).

Table 2: Cases of craniofacial duplications in goat

Breed/Sex	Classification	Description	Reference
	Dicephalus	A single fused head which joined together at the forehead and bifurcated at the beginning of the jaw.	Pal and Verma, 1981
♀	Diprosopus	Partial duplicated head possessed 4 eyes, 2 ears, 2 maxillae, 2 mandibles, 2 mouths, 2 noses, 2 cerebri but 1 cerebellum in the cavum cranii. No duplication was observed in the neck, thorax, abdomen, and limbs.	Sönmez et al., 1992
♀	Dicephalus	Externally, the kid had two heads, four eyes (the right medial was small 'microphthalmos'), three ears and two mandibles. The two heads were joined together at the level of the second cervical vertebra and thereafter connected with a single trunk. The roof of each buccal cavity had identical cleft palates 'palatoschisis'. The spinal cords were joined at the second cervical vertebra. The kid had 2 tongues, 2 epiglottisses, 2 thyroids, 2 oesophagi, 2 pairs of lungs, 2 spleens and 2 livers. The oesophagi had joined together before piercing the diaphragm to enter the rumen. The left heart assumed a solid mass with a moderate-sized aortic arch together with a brachiocephalic trunk. The right heart was small and assumed the shape of a pocket.	Ramadan, 1996
East African/♂	Diprosopus	The goat kid had a gross deformity confined only to the face, characterized by a dome-shaped skull, duplication of eyes, mouth and nostrils. The medial eyes were partially fused and occupied a single orbit and were blind. Two other lateral eyes were in the normal position. There were double nostrils with one on either side of the head, ventral and lateral to the central eyes. A tongue protruded from each oral cavity. The left oral cavity had the lower lip deviated centrally. The two faces shared a medial cheek and normal-appearing ears were seen bilaterally, but no ears were present on the medial side. Radiographs of the head showed two sets of jaws, three orbits, a normal single trunk, and normal limbs. The vertebral column, ribs, sternum, abdomen, and thoracic and pelvic limbs appeared normal.	Mukaratirwa and Sayi, 2006
♀	Dicephalus	Radiological examination showed a single axial and appendicular skeleton caudal to the head region. In the head, there was partial fusion of the two skulls starting at the caudal part of the frontal bone (caudal to the orbit) and proceeding caudally (i.e., fused parieto-temporaloccipital regions), resulting in a single cranial cavity and a single brain. The goat kid had two faces of nearly equal size, resulting from mandibular and maxillary duplication. Each face presented two eyes, with two optic nerves, two nostrils, and a mouth. However, each face had one ear laterally. Each of the four nostrils led into a nasal cavity. The two tongues were joined at their root just rostral to the single epiglottis. Two separate, complete oral cavities were noted; each oral cavity showed buccal and labial vestibule and an oral cavity proper. Each of the oral cavities ended caudally by the oropharynx. Tracing of the plastinated slices showed that the two oropharyngeal cavities merged caudally, and revealed the presence of a single nasopharynx, single laryngeopharynx, single esophagus and single larynx.	Elnady and Sora, 2009
♂	Dicephalus		Favaretto et al., 2011

♂	Dicephalus	The kid had a single body with duplicated symmetrical heads attached to single neck. Externally, the dicephalic kid had a single body with duplicated heads that were of almost the same size and shape, 4 eyes, 4 ears, 2 mandibles, 2 maxillae. Necropsy revealed complete nasopharynx, oropharynx, laryngopharynx, and normal tongue in each head. The lamb had two separate brains and two cerebella. Both cerebellums were hypoplastic in variable degrees. The tongue and larynx in each head were normal and the esophagus was duplicated. The kid had two tracheas and one lung. The lung had many lobes.	Farjani Kish and Mohammadi, 2014
♂	Dicephalus	Both the heads were nearly of same size and were joined from the occipital and temporal regions at an angle of 45°.	Ahmed et al., 2015
♀	Dicephalus	The dead fetus had a single body with duplicated symmetrical heads attached at the level of occipital region. Regarding axial skeleton, there was complete duplication of skull with fully developed brain in both the cranial cavities. Both brains showed fully developed cerebral hemispheres, cerebellum, pons, and medulla oblongata. Both the brain stem continued and joined to form a single spinal cord at the level of first cervical vertebra (atlas). Neck muscles were developed bilaterally, and supra spinous ligament was single at its origin and divides into two at the thoraco-lumbar region and continues as divided up to the head and fused at the level of occipital. Two separate esophagi ran up to thoracic inlet and fused at the cranial media sternum.	Kavitha et al., 2018

Symmetric conjoined twins on the ventral surface of the bodies

These twins are joined at various sites and extend across the cranio-thoraco-abdomino-omphalic-caudal region of the bodies. According to NEV (2017), they exhibit a median junction which is named craniothoracalis, xiphoidea, sternalis, thoracica, thoracico-epigastrica, coxalis or pelvica. The cases relevant to this anomaly are summarized in Table 3 and some specimens are illustrated in Figure 1.

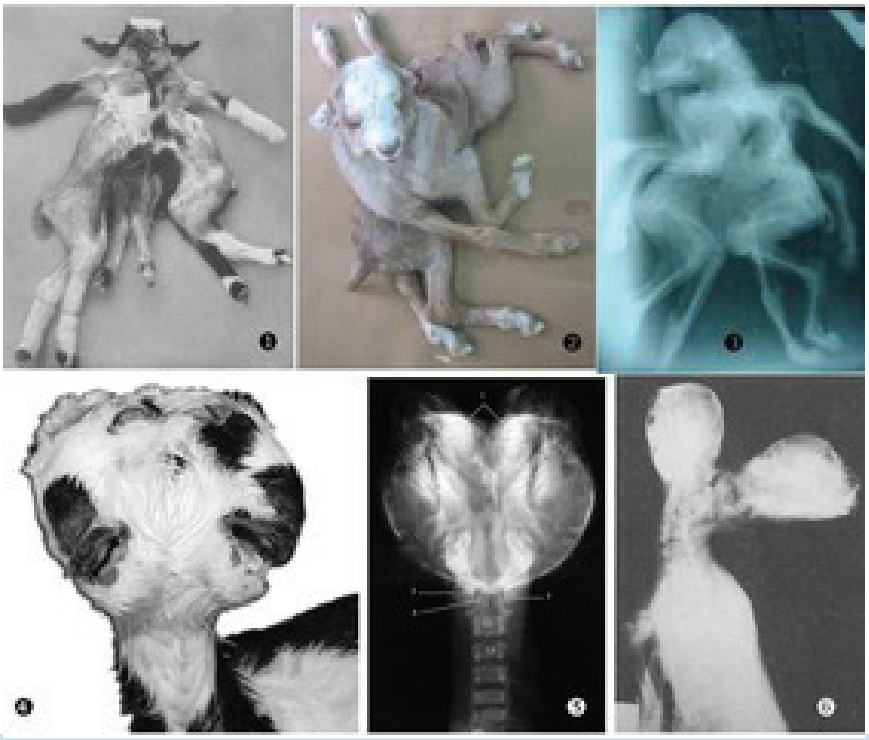


Figure 1 A. Cephalothoracopagus monosymmetros monoprosopus [Arndt, 1925]; B. Monocephalus thoracopagus [Shojaei et al.,2015]; C. Monocephalus thoracopagus dipygus [Buhari et al., 2008]; D. Cranioventral aspect of a dicephalus kid showing facial duplication [Elnady and Sora,2009]; E. Dorsoventral radiograph of dicephalus kid [Elnady and Sora,2009]; F. Ventrodorsal radiograph of a dicephalic goat kid [Ramadan, 1996].

Table 3: Cases of ventrally conjoined symmetric twins.

Breed/Sex	Classification	Description	Reference
♂	Cephalothoracopagus monosymmetros monoprosopus	The height of the individuals was 64cm and 68cm whereas their weight was 2730 gr. The trunk and the skeleton of the extremities were completely double (up to the first cervical vertebra). The single cranium possessed 2 foramina occipitalis. The two spinal cords converged at the level of the paired medulla oblongata. The kids had in common 1 pons, 1 cerebellum and 1 pituitary gland. The cranial nerves 11 and 12 were double. The single heart was enclosed in one pericardium and was significantly enlarged. However, there were 2 aortae. The respiratory system was composed of 4 lungs (2 bigger and 2 smaller) and a common trachea and larynx, there was a single thymus and thyroid gland. The digestive tube comprised a simple oral cavity, tongue, throat, and esophagus. The rumen and reticulum were double, whereas the omasum and abomasum were single. Regarding the intestine, the duodenum and jejunum were simple whereas the ileum, caecum colon and rectum were double. The twins possessed two livers, one typically formed, the other rudimentary without gallblader. A spleen was found in one id whereas the other id possessed 2 spleens (a larger and a smaller). The genito-ururinary system was double and normal	Arndt, 1925
	Monocephalus tetrabrachius tetrapus dipygus		Najume et al.,1990
	Monocephalus thoracopagus tetrapus tetrabrachius		Mitra et al., 1994
♂	Monocephalus thoracopagus dipygus	Radiographic examinations revealed fully developed skeletal system except for single head (monocephalus) and some deviation of the ribs. The twins were joined at the thorax (thoracopagus) and had a fully developed heart in one of the twins and a rudimentary one in the other. There were three kidneys: two in the twin with the developed heart and one in the other twin. The twins shared common liver and rudimentary lungs.	Buhari et al. 2008
	Monoprosopus abdominocephalophagus diacaudatus tetrabrachius tetrascelus		Sonfanta et al. 2010
Chamois/♀	Thoraco omphalopagus	Two identical and symmetrical twins fused from the manubrium sterni to the region just caudal to the umbilicus. The rib cages were conjoined in the ventral plane with a single set of pericardial, pleural, and peritoneal cavities. Internal examination revealed the presence of a common diaphragm and a single enlarged liver. Within a single central pericardium, two malformed hearts were present.	Binanti et al. 2012

♀	Monocephalus thoracopagus	The twins had on head, 4 ears, 4 paired limbs and 2 bodies. Necropsy revealed that duplication of the axial skeleton had progressed to the level of the basilar bones of the skull. The central nervous system was also duplicated completely to the level of the metencephalon. Two tracheae were attached to the larynges proximally and had coursed distally to form four separate lungs. Each twin had a complete female urogenital system. Each twin had a heart with a normal pulmonary trunk and two ascending aortae. The digestive system had remained single up to the end of the esophagus. But partial duplication was seen in the rumen and reticulum. The common omasum was situated in the middle of the two reticula and had continued to the abomasum distally. Following the common pylorus, two duodenums had entered each abdominal cavity of two bodies and continued by distal parts of two sets of intestines. These parts had developed primitively somehow the jejunal loop and the spiral colon were not seen.	Shojaei et al. 2015
Red Sokoto/♀	Thoraco omphalopagus	The conjoined kids were attached from thorax to the caudal umbilicus. complete duplication of the head and neck down to the thorax. Complete duplication of the vertebral column (thoracic, lumbar, and sacral vertebrae), anus, vulva, and tail. Two forelimbs attached on each kid in normal spatial orientation. shared umbilical cord, and two unattached pelvises with two hind limbs on each twin at normal positions. Autopsy revealed complete fusion of the thoraces and abdomen to the caudal umbilicus at ventral midline, two pairs of normal rib cages ventrally joined by 2 sterna, two completely divided but attached thoracic cavities containing only one hypertrophic heart. The attached thoraces were separated from the abdomen by a single diaphragm. In the abdominal cavity of each twin, the gastrointestinal tract was duplicated. However, a single enlarged liver and a gall bladder were found only in kid. Each twin contained a normal urogenital system	Ahmad et al. 2019

Symmetric conjoined twins on the cranial or pelvic region

If the twins are joined in the cranial region are called craniopagus. A case of craniopagus kid was described by Pandit (1994). If the twins are joined in the pelvic region are called ischiopagus.

A female kid possessed partial duplication of the lumbar vertebral column. From the fourth to the sixth lumbar vertebrae a radiolucent line divided the vertebral body in two halves. The kid had two pelvises. One principal pelvis established articulation with the two principal hind limbs and with the sacrum bone. Another secondary pelvis (extra set) was also visible but there was no articulation with the sacrum. Other associated malformations were palatoschisis (cleft palate) and anal atresia. Necropsy revealed a distended rectum and colon containing meconium and an atrophic right kidney placed within the pelvic space of the extra set pelvis (Gorbera, 2005).

A newborn five-legged male kid showed three pelvic limbs at the pelvic region. Two anuses were present. Necropsy revealed that duplication occurred in the internal organs as well as the bony pelvic girdle. Four sets of hip bones, positioned sequentially from left to right were seen. Spina bifida was present at the sacral region. The digestive system was formed normally up to the distal part of the jejunum, beyond which the gut was duplicated distally to form two complete sets of ileum, caecum, colon, rectum, and anus. Two bladders were observed. Each bladder was continued by a urethra. Except for the testes, two normal testicular structures were situated near the kid-

neys. Two caudal mesenteric arteries were identified (Shojaei et al., 2012).

Unequal conjoined twins

The Gemini asymmetrici include the parasite which is normally visible on the external surface of the autosite and may be randomly oriented on any surface (epigastrium, head, sacrum, or pelvis). However, most of these cases represent a duplication of the caudal region (dipygus) with an attachment of a parasitic or rudimentary pelvis and one or two rudimentary limbs in and around the perineum or pelvis of the autosite, as the findings reported here.

An autosite with a duplication involving the hindgut was identified by Otiang'a-Owitti et al. (1997). The case report discussed here was presented as a non-viable specimen with a normal-looking body, two anal openings, two sets of the external genitalia, and an attached parasitic twin represented by a caudoventral mass with two limbs. Within the region of the pelvic and perineum, there was a parasitic twin, which was directed ventrally between the two normal hind limbs. The external form of this caudoventrally located parasite consisted of an ovoid mass that resembled the lower part of the trunk with two well-developed limbs that were shorter than the normal autosite limbs. These limbs were flexed, directed cranially, and responded positively to induced flexure. Each possessed normal components (skeleton and muscular) of the hind limbs. Because the co-twin occupied parts of the inguinal area, the two mammary glands of the host were positioned slightly cranially to occupy the area between the ventral abdominal wall and the lower wall of the parasite. There were no tail, perineum, or openings on the parasite's surface. The parasitic skin was continuous with that of the autosite at all points of attachment.

Dissection of the trunk-like mass of the parasite revealed a mass of adipose tissue with neither vertebral structures nor visceral organs. A few small nerve bundles were evident subcutaneously. The two limbs were not fused to each other but were entirely separate.

Dorsal to the parasitic twin, there were two anal openings and two sets of external genitalia. When viewed from the caudal aspect, the two anal openings were separate from each other and were symmetrically placed on either side of the perineal midline, in line with their corresponding external genitalia. The gastrointestinal tract was single and was relatively normal up to the level of the mid jejunum, where it bifurcated. From this point onward, the remainder of the intestinal tract was doubled or duplicated. All the components of a normal intestinal tract at this level were evident, with mirror-image jejunum, ileum, cecum, colon, rectum, and anal openings. The arrangement within each of the two duplicated portions was identical to that normally seen in a dissection of an adult goat. The two large bowels were of normal size and shape and were completely separate.

The two normal-appearing vulvae were widely separated from the midline and were located more toward the lateral aspect of the perineum. Internally, each vulva led to separated internal genitalia that were mirror images of one another. Each genital tract had a vestibule, clitoris, vagina, cervix, unicornous uterus, and ovary. Furthermore, each tract was suspended from the body wall by a single fold of the peritoneum that represented part of the broad ligament. There were two completely separate urinary bladders, each firmly anchored by connective tissue to the ventral surface of the vagina. Each received a single ureter and emptied into an individual urethra located on the floor of the vestibule. Both urinary bladders were of relatively normal size with an apex, body, and neck. The autosite had two kidneys of normal size, and each emptied into the ipsilateral bladder via a single ureter. Each tract within the pelvic viscera of the autosite had its own fold of tissue that suspended the viscera from the body wall. In addition, there were no connections between these pelvic viscera and any tissues of the twin appendage. Finally, no notable anomalies were discernible in the autosite's head, neck, or thoracic viscera.

FREE ASYMMETRIC TWINS

In the free asymmetric twining phenotype, there is total separation of the twins. However, one individual is less formed. When the more important part of the less formed fetusis missing, is termed Acardius. Acardius twins are subdivided into four morphologic categories. If the Acardius lacks the head is termed acephalus, if the trunk is absent is termed acormus and if the Acardius is an undefined structure is called Acardius amorphous. Finally, Acardius anceps represents the most highly developed form in which the body and extremities are developed, and the head is partly developed (Napolitani, 1960). In goats, cases of acardius acephalus and acardius amorphous (Figure 2) have been recorded, which are quoted in Table 4.

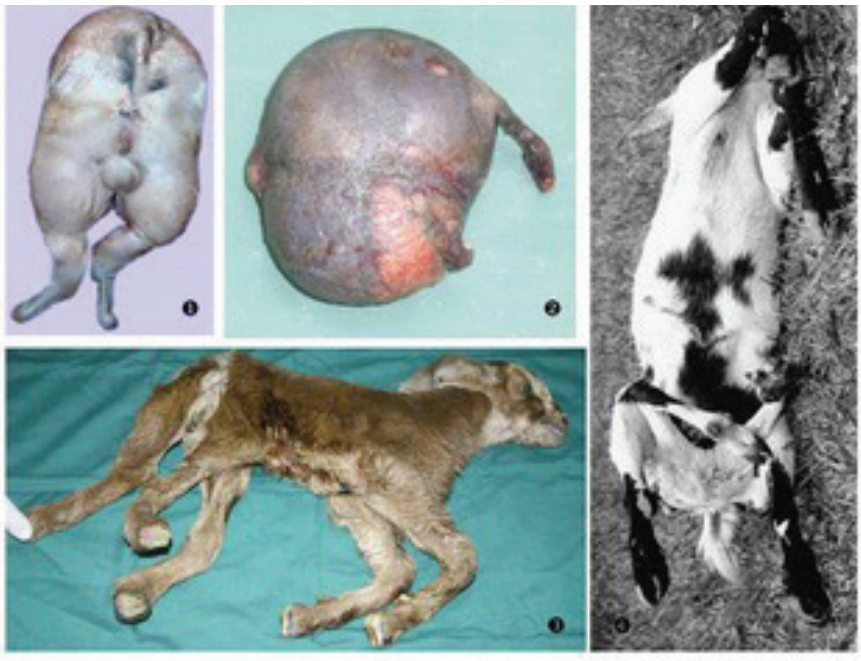


Figure 2. A. Acardius acephalus [Dinesh et al.,2020]; B. Acardius amorphous [Anwar et al, 2009]; C. Monocephalus tripus dibrachius [Shojaei et al., 2012]; D. Heteropagus parasitic twins [Otiang'A-Owitti et al.,1997].

Table 4: Cases of caprine acardius monsters

Breed/Sex	Classification	Morphometrics	Description	Reference
♂	Acardius amorphus	10.5X8.5X 1.8cm	The fetous was covered with dense hairs.	Schmincke 1921
	Acardius amorphus	8X3cm	Egg-shaped flattetened and hairy mass.	
Kani-adu	Acardius amorphus	786gr, 9.3X6.1X3.4cm	The anomalous fetus was covered with pigmented skin with a few hairs. One pole of the anomalous fetus had a soft tissue protuberance and the other had 2 unequal and undifferentiated limbs. The radiographic image showed an irregular round soft tissue mass with soft tissue protrusion on 1 side and a partly developed appendicular structure with undifferentiated bone and a rudimentary appendicular protrusion on the other side	Anwar et al. 2009
Black ♂	Acardius acephalus		Radiological projections revealed the presence of a disproportionate area of soft tissue embedding the two hind limbs, the pelvis, and a malformed portion of the vertebral column. Hind limbs were morphologically unremarkable. The vertebral column appeared malformed, turned at an angle of 90° and cranially shifted. Externally, the foetus was oedematous with only a pair of limbs joined to a bony structure not better identified at palpation. External genitalia were represented by two uninhabited sketched scrotum. The head, abdomen and thorax were not identifiable. The hind limbs were normally developed over their entire length; the vertebral column appeared crushed and malformed. An omphalocele and an immature preputial sheath, internally connected to a rudimentary urethro-penial structure in continuity with the urinary bladder, were detected. The intestine was comprised only of an ileum, an atretic, dilated and blind caecum and a colon	Macrì et al. 2013

	Acardius acephalus			Balasubramanian et al. 2015
	Acardius acephalus		The head, neck and fore limbs were completely absent. The posterior half of the fetus was developed with distinct hind limbs. The complete mass was flaccid due to the lack of skeletal support. On examination of the thoracic cavity, a portion of thoracic vertebrae were only present with organs such as liver, spleen, kidney and intestines, lungs, heart, anal opening, and primary sex organs were absent.	Palanisamy et al. 2018
Tellicherry ♂	Acardius acephalus	800gr	2 normal kids, without head, ears alone were found in the anterior part of the neck and other external body parts were normal. Post-mortem examination revealed no abnormalities in visceral organs like heart, kidney, liver, and Lung etc.	Thirunavukkarasu et al. 2019
♂	Acardius acephalus	1.5kg	Head, neck, and forelimbs were completely absent. The posterior half of the fetus was developed with distinct hind limbs. The hind limbs were normally developed over their entire length but adactyly (absence of digits) observed. While opening the skin generalized anasarca was noticed on the fetus. On examination of thoracic cavity revealed that the absence of lung except for excessive soft tissues. An abdominal cavity examination revealed that coiled recognizable size mass without a clear stomach and intestine. In the lower abdomen only a rudimentary kidney with no urinary bladder and other structures.	Dinesh et al. 2020

DISCUSSION

In a 2-year survey, two conjoined twins were detected among 1092 newborn goats of Saanen breed and Saanen crossbreds (Basrur, 1993). This is the sole survey regarding the incidence of caprine congenital malformations and therefore of caprine congenital twinning.

Numerous classifications of conjoined twins are available, based on anatomy, site of union, symmetry level of twins and embryological development. Abnormalities in the anatomy of conjoined twins arise during prenatal development. The implications of these abnormalities can lead to organ dysfunction, organ failure or even death. Genetic and environmental factors are thought to be the main causes of the development of conjoined twins. At present, two hypotheses (partial fission versus secondary fusion) are used to explain the mechanisms behind the formation of conjoined twins (Boer et al., 2019). Although both theories are postulated throughout the literature, controversies remain existing. The fission theory, which assumes that conjoined twins originate around the primitive streak stage of embryonic development, is more postulated in textbooks, whereas the model of secondary fusion is a widely accepted premise in current research papers (Spencer, 2000a, 2000b). In addition to the fission and fusion theories, a third scenario to explain conjoined twins may be the initial "crowding and thereby duplication of morphogenetic potent primordial" (Boer et al.,2019). The latter authors proposed that the initial duplication of axially located morphogenetic potent primordial in one inner cell mass is the initiating factor in the formation of ventrally, laterally, and caudally conjoined twins. The dorsally conjoined twins, the craniopagus, rachipagus, and pygopagus, not only are the easiest to explain but also provide the most convincing evidence for the ''fusion" theory (Spencer, 2000a, 2000b).

Parasites may result from the demise of one twin, perhaps originally defective, with surviving supernumerary structures (the parasite) attached to and vascularized by the more normal twin (the autosite), always at or near one of the usual sites of union (Spencer, 2001).

The cases of free monozygotic twins are among

the malformations encountered in goats. Their incidence is greater than generally believed. The pathogenesis of this abnormality (acardius) is thought to be due to reversed arterial perfusion. Oxygen- and nutrient-depleted umbilical artery blood leaves the normal twin and is driven into the abnormal twin by way of anastomoses with its umbilical artery. Two pathogenetic hypotheses are currently accepted. The first hypothesis suggests that there is a primary defect in the development of the heart and that the acardius twin only survives because of the compensatory anastomoses that develop. The second states that the acardius twin begins life as a normal foetus, and that a reversal in the circulatory blood flow results in atrophy of the heart and other organs (Macrì et al., 2013). Among eight cases of acardius surveyed in the present review, three were classified as amorphous, whereas five were as acephalus.

In the group of equal conjoined twins (Table 3), the kids usually are joined mainly across the heads and/or the thoraxes, and/or the abdomens and presumably possess two pairs of forelimbs and two pairs of hind limbs. However, we must point out, that the description and classification of these malformations is many times vague and ambiguous.

Cephalic parapagia is classified as diprosopia or dicephalia (Hiraga and Dennis,1993). Diprosopus twinning refers to a single body and a single head, showing a spectrum of duplications of craniofacial structures with great variability in their site of union and degree of organ sharing. In the most extreme form of diprosopus twinning, two complete faces/snouts are seen, whereas the mildest form may present only isolated duplication of the nose. Dicephalus refers to two totally separated heads.

The developmental mechanisms by which duplication of the naso-facial structures occurs have been attributed to duplication of the neural crest derivatives. Derivatives of the neural crest are supposed to be partially or totally duplicated when there is an initial duplication of the notochord leading to two neural plates and subsequently duplicated neural crests (Carles et al., 1995). Among the nine craniofacial duplications surveyed, only two diprosopus were recorded; the rest were various aspects of dicephalus.

Regarding the sex of twins, in the cases which were surveyed in the present review, variations were observed according to the group of malformations. In the group of acardius four males were detected over eight reported cases. In the group of craniofacial duplications, four males and four females were recorded. Three females and two males were registered in the cases of equal conjoined twins. The abnormal twinning of kids has occurred independently of the breed.

The occurrence of abnormal twins and especially conjoined twins in animal husbandry leads to losses in animal production. Thus, it is very important to investigate and understand what causes the formation of this defect. To facilitate this process, it is necessary for breeders to report each case of twins, and to conduct strict and improved farm practices including karyotyping and prevention of accidental mating. In order to allow further scientific investigation, breeders should provide necessary information about the ancestors of animals, animal welfare conditions, their nutrition, vaccinations, illnesses, etc. Such information could facilitate the identification of pathogens. In some cases, the environments in which livestock live are severely restricted, so the identification of teratogenic factors is also crucial. The priority should be to understand the causes of this defect to prevent its occurrence.

CONCLUSIONS

The relationship between the abnormal reproductive features in these twins and the conjoining is unclear. The anatomy of these twins, in addition to the literature reviewed, illustrates the internal anatomical heterogeneity of grossly similar conjoined twins. Areview of the literature also suggests that conjoined twinning may be more common in caprine than was previously suspected. Each case of abnormal twins should be treated as unique due to the presence of peculiar anatomical differences. These differences are particularly important but because there is no planning, resources and procedures for separation, a big amount of knowledge is lost. Advanced prenatal screening techniques in animals are very rarely used and conjoined twins are often only diagnosed during or after a dystocia. Difficult births in animals can cause the death of a female or/and offspring(s) and contribute to reproductive wastage in animal production.

In conclusion, the establishment of a national registry for animal malformations is crucial. Therefore, we present a few aspects to a successful founding of such registry:

Collaboration: Encourage veterinarians to collaborate with relevant authorities, such as the Hellenic Veterinary Medical Association, government agencies, and research institutions. Collaboration will help ensure the registry's success by leveraging expertise, resources, and data sharing.

Standardization: Advocate for standardized data collection methods, terminology, and classification systems. This will enable accurate and consistent reporting of malformations, facilitating data analysis and comparisons across different cases.

Confidentiality and Privacy: Emphasize the importance of maintaining confidentiality and privacy when collecting and storing data. Veterinarians should obtain informed consent from animal owners and adhere to relevant data protection laws and regulations.

Comprehensive Data Collection: Encourage veterinarians to gather comprehensive data on each malformation case, including animal species, breed, age, sex, geographic location, clinical presentation, genetic information (if available), and any known exposure to potential teratogens. The more data collected the better insights can be gained.

Longitudinal Tracking: Establish a mechanism to track malformation cases longitudinally. This will enable monitoring of trends over time, identification of potential risk factors, and evaluation of the effectiveness of preventive measures.

Reporting and Analysis: Advise veterinarians to report malformation cases to the registry in a timely manner. Encourage the analysis of collected data to identify patterns, geographical clusters, potential causes, and emerging trends. Regular reporting and analysis can provide valuable information for research, policy-making, and public awareness.

Educational Outreach: Promote educational initiatives for veterinarians, pet owners, and the general public regarding the importance of reporting malformations and the role of the registry. Increasing awareness can encourage active participation and contribute to a more comprehensive and accurate database.

Research Collaboration: Encourage collaboration with academic institutions and researchers interested in studying animal malformations. Collaborative research efforts can lead to a better understanding of the causes, prevention, and treatment of malformations, benefiting both animal health and human health (as some animal malformations may have underlying environmental or genetic factors that could also affect human health).

Regular Updates: Ensure that the registry is regularly updated, maintained, and accessible to relevant stakeholders. Periodic reports summarizing the findings and trends can be disseminated to veterinarians, researchers, and policymakers to inform decision-making and improve animal health outcomes.

Continuous Improvement: Encourage veterinarians to seek feedback from users of the registry and make necessary improvements based on their input. Continuously evaluating and enhancing the registry's functionality and usability will help maximize its impact.

REFERENCES

Ahmad I, Chafe U, Umar A, Salisu M (2019) Conjoined Twins in Red Sokoto Goat. J Hellenic Vet Med Soc70(4):1919-1924.

Ahmed A, Jena B, Mishra GK, Tiwari RP (2015) A rare case of congenital dicephalic iniodymus defect in nondescript caprine neonate. J Livest Sci 6:10-12.

Anwar MT, Khan AI, Balasubramanian S, Jayaprakash R, Kannan TA, Manokaran S, Asokan SA, Veerapandian C (2009) A rare case of globosus amorphus in a goat. Can Vet J 50:854-856.

Arndt HJ (1925) Cephalothorakopagus monosymmetros monoprosopus von der Ziege. *Virchows* Arch Pathol Anat Physiol Klin Med 255:1-16.

Arthur GH (1959) Co-joined twins-the veterinary aspect. Vet Rec 68:389-393.

Balasubramanian S, Sathiamoorthy T, Ganesh R (2015) A Rare Case of Holocardius Acephalus Fetal Monster in a Non -Descriptive Goat. Indian Vet J 92(2):50 - 51.

Basrur PK (1993) Congenital abnormalities of the goat. Vet Clin North Am Food Anim 9:183-202.

Binanti D, Riccaboni P (2012) Thoraco-Omphalopagus Conjoined Twins in Chamois- Coloured Domestic Goat Kids. Anat Histol Embryol 41:159-162.

Boer LL, Schepens-Franke AN, Jan Oostra R (2019) Two is a crowd: On the enigmatic etiopathogenesis of conjoined twinning. Clin Anat32:722-741.

Buhari S, Yakubu AS, Jibril A, Adeyanju JB, Chafe UM (2008) Monocephalus, thoracopagus and dipygus twins in Sokoto Red goat. Sokoto J Vet Sci 7(1):23-24.

Carles D, Wiechhold W, Alberti E, Leger F, Pigeau F, Horovitz J (1995) Diprosopia revisited in light of the recognized role of neural crest cells in facial development. *J Craniofac Genet Dev Biol* 15(2):90-97.

Corbera J A, Arencibia A, Morales I, Gutierrez C (2005) Congenital Duplication of the Caudal Region (Monocephalus Dipygus) in a Kid Goat. Anat Histol Embryol 34:61-63.

Dinesh M, Kalaiselvan E, Manikandan R (2020) A rare case of Holocardius acephalus monster with fetal anasarca in a non-descriptive goat kid. Pharma Innov 9(11):01-04.

Elnady F, Sora MC (2009) Anatomical exploration of a dicephalous goat kid using sheet plastination (E12). Congenit Anom (Kyoto) 49:66-70.

Farjani KG, Mohammadi H (2014) Congenital defect (Dicephalus) in a newborn goat: case report with literature review. Comp Clin Path 23:233-236.

Favaretto L, Nascimento EM, Kirnew MD, Nagashima JC, Astrauskas JP, Filadelpho AL, Birck AJ, Peres JA, Barcelos RP (2011) Dicefalia in goats -Case Report .*Rev Electron de Vet* 9:11.

Hiraga T, Dennis SM (1993) Congenital duplication. Vet Clin North Am Food Anim 9:145- 161.

International Committee on Veterinary Embryological Nomenclature (ICVEN) (2017) Nomina Embryologica Veterinaria. 2nd ed, Ghent, Belgium.

Kavitha K, Monica G, Sarath T, Kannan TA, Joseph C, Arunmozhi N, Balasubramanian S (2018) Dystocia due to Diprosopus Parapagus fetus and its Successful Delivery through C- Section in a Non-Descript Goat. Theriogenology Insight 8(3):149-153.

Macrì F, Lanteri G, Ferraro S, Marino G, Mazzullo G (2013) Acardius acephalus in a goat kid - radiological and gross findings: a case report. Vet Med (Praha) 58(11):591-593.

Mitra M, Basak DN, Chakrabarti A (1994) Monocephalus thoracopagus tetrapus tetrabrachius monster in a Black Bengal goat. Indian Vet J 71:177-178.

Mukaratirwa S, Sayi ST (2006) Partial facial duplication (diprosopus) in a goat kid. *J S Afr Vet* Assoc 77(1):42-44.

Najume NGI, Shehu NAS, Celestine ON (1990) Monocephalus dipygus twins in Sokoto Red goat. Zariya Veterinarian 5(2):107-109.

Napolitani FD, Schreiber L (1960) The acardiac moster: a review of the word literature and presentation of two cases. *Am J Obstet Gynecol* 80:582-589.

Otiang'A-Owiti GE, Oduor-Okelo D, Kamau GK, Makori N, Hemdrickx AG (1997) Morphology of a six-legged goat with duplication of the intestinal, lower urinary, and genital tracts. Anat Rec 247:432-438.

Pal M, Verma JD (1981) A unique case of monstrosity in a goat. Indian Vet J 58:224.

Palanisamy M, Manokaran S, Raja S, Prabaharan V, Rajkumar R, Jayaganthan P, Arulkumar T, Sasikala M (2018) Dystocia Due to Holocardius Acephalus Fetal Monster in a Goat - A Case Report. Indian Vet J 95(6):61-62.

Pandit RK, Pandey SK, Aggarwal RG, (1994) A case of dystocia due to diplopagus monster in goat. Indian J Anim Reprod 15(1):82.

Ramadan RO (1996) A dicephalic goat with other defects J Vet Med A 43:337-343.

Schmincke A (1921) Vergleichende untersuchungen über die anlage des skelettsystems in tierischen mißbildungen mit einem beitrag zur makro- und mikroskopischen anatomie derselben. *Virchows* Arch Pathol Anat Physiol Klin Med 230:564-607.

Shojaei B, Mohebbi E, Hashemnia S (2012). Caudal duplication (monocephalus tripus dibrachius) in a kid goat. Eur J Anat 16 (3):206-211.

Shojaei B, Nadimi N, Esmaeilzade S (2015) Monocephalus thoracopagus conjoined twins in a goat. Iran J Vet Sci Technol 7(1):56-62.

Sonfada ML, Sivachelvan MN, Haruna Y, Wiam IM, Yahaya A (2010) Incidence of Congenital Malformations in Ruminants in the North Eastern Region of Nigeria. Int J of Anim Vet Adv 2(1):1-4.

Sönmez G, Özbilgin S, Serbest A, Misirlioğlu, D (1992) Bir Oğlakta Diprosopus olgusu. J Res Vet Med 11:93-98.

Spencer R (2000a) Theoretical and analytical embryology of conjoined twins. I. Embryogenesis. Clin Anat 13:36 -53.

Spencer R (2000b) Theoretical and analytical embryology of conjoined twins. II. Adjustments to union. Clin Anat 13:97-120.

Spencer R (2001) Parasitic Conjoined Twins: External, Internal (Fetuses *In Fetu* and Teratomas), and Detached (Acardiacs). Clin Anat 14:428-444.

Thirunavukkarasu M, Pavithra S, Vigneshwaran S, Shanmuganathan S (2019) An acephalus monster in a kid: A case report. Pharma Innov 8(6):04-05.